National Aeronautics and Space Administration

Airport Noise Tech Challenge Overview

Tech Lead: James Bridges

High Speed Project
23-24 April 2013

High Speed Project

Develop and Validate Tools, Technologies and Concepts to Overcome the Barriers to Practical High Speed Vehicles

Vision

- A **supersonic noise standard** to replace the current prohibition of overland supersonic flight
- Technologies that enable new generations of aircraft that provide the benefits of supersonic travel in a future air transportation system

Scope

- Civil Supersonic Aircraft: business class to supersonic airliners
- Partnership with the DoD for development and validation of scramjet propulsion system

Technical Challenges (2013 – 2017)

- Low Sonic Boom Design Tools (2015)
- Sonic Boom Community Response Metric and Methodologies (2017)
- Low Noise Propulsion for Low Boom Aircraft (2016)

Research Progress Underlies High Speed Tech Challenges

Sonic Boom Breakthrough

- *Methodologies for the development of aircraft with shaped sonic boom signatures, particularly in the aft end of the vehicle, have been applied and validated through wind tunnel testing. Low boom targets for N+2 configurations have been met; methods are applicable to N+1 and N+3 vehicles as well.*
- *Next Steps: Full carpet optimization, detailed propulsion effects*

Airport Noise

- Intermediate scale acoustic tests of 3 stream nozzle designs completed
- Modified designs should reach goal
- Next Steps: Integration effects, inlet & fan noise assessment and reduction

Cruise Emissions

- NO_X goals demonstrated in flametube testing
- Next Steps: reduce combustion dynamics, scale up to sector test

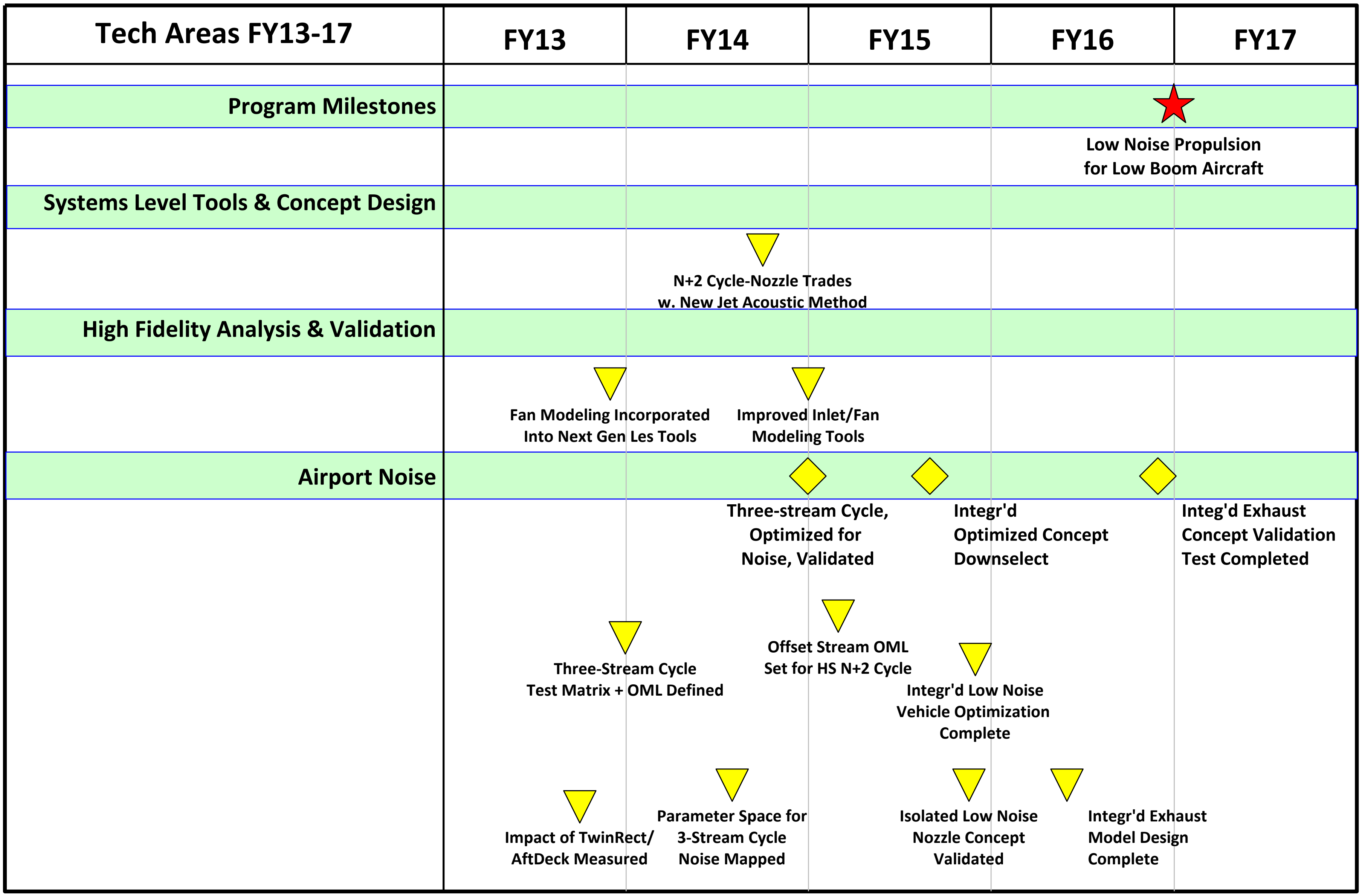
Balanced Goals for Practical Civil Supersonic Aircraft (Technology Available)	NASA N+2 Validation Study Goals	N+2 System Validation Results
Design Goals		
Cruise Speed	**Mach 1.6 -1.8**	**Mach 1.6 - 1.8**
Range (n.mi.)	**4000**	**4000 - 5500**
Payload (passengers)	**35-70**	**35-80**
Environmental Goals		
Sonic Boom	***85 PldB (revised)***	***79 - 81 PLdB***
Airport Noise (cum below stage 4)	**10 EPNdB**	***12 EPNdB***
Cruise Emissions (Cruise NOx g/kg of fuel)	**< 10**	***5***
Efficiency Goals		
Fuel Efficiency (pass-miles per lb of fuel)	**3.0**	**1.6 – 3.1**

Boeing Concept

Lockheed Concept

Low Noise Propulsion
Tech Challenge Key Milestones

- Program-Level 1 Milestone
- Project-Level 2 Milestone
- Key Level 3 Milestone
- Key Level 4 Milestone



HS Airport Noise WBS

- HS 5.1 Prediction Tools
  - 5.1.1 Empirical Tools
  - 5.1.2 RANS-based Tools
  - 5.1.3 Time-accurate Tools
- HS 5.2 Noise Optimization Studies
  - 5.2.1 Three-Stream Concepts
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Current Tasks
Future Tasks

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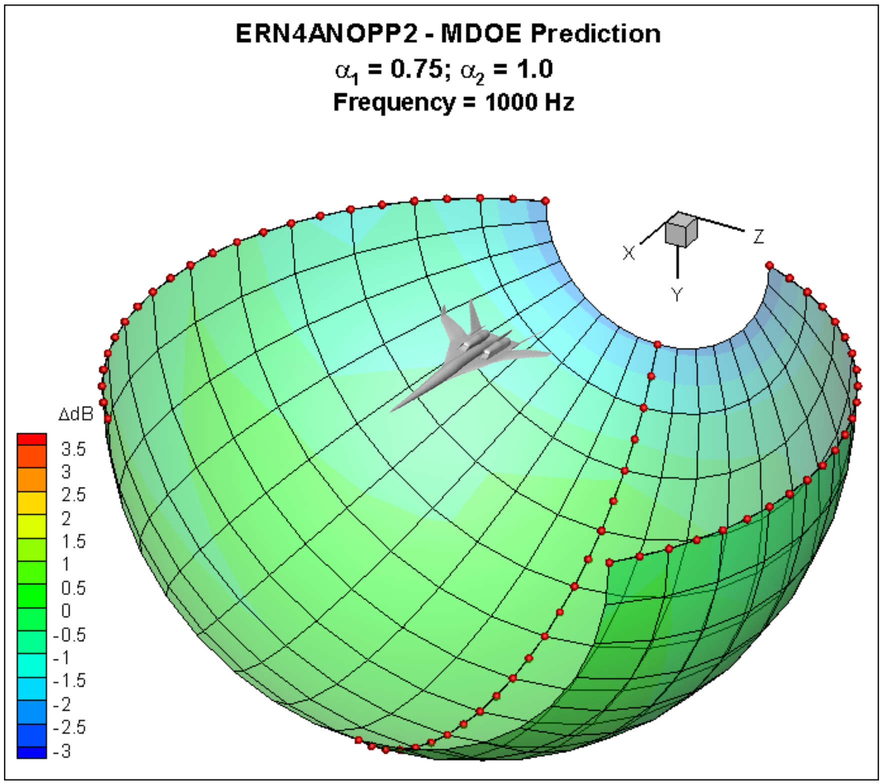
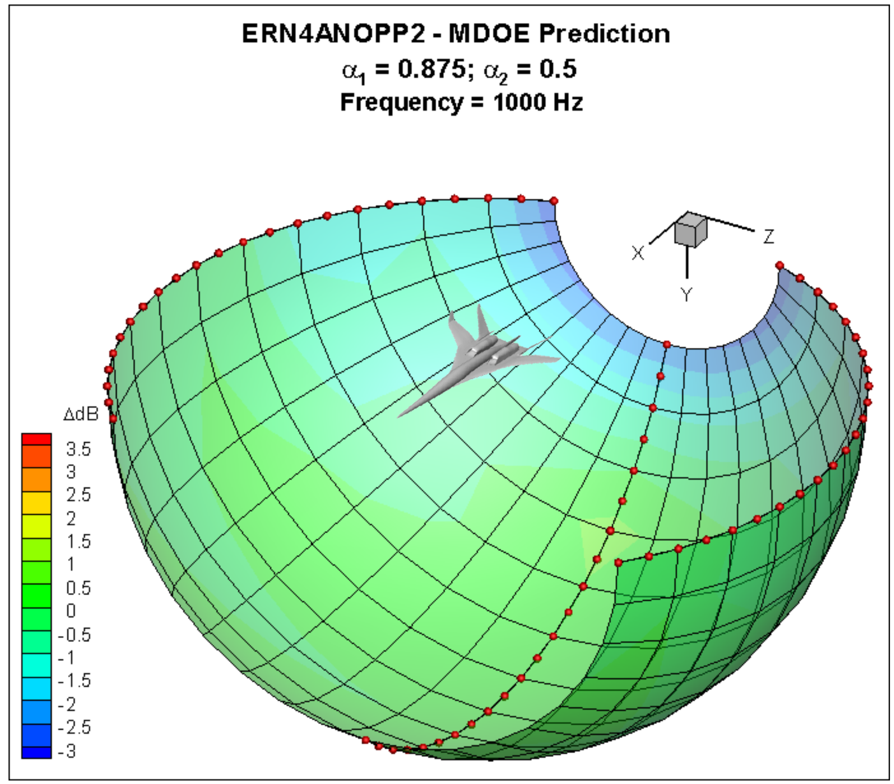
T5.1.1 Empirical Tools

51101 ANOPP2 model integration

- Impact of aspect ratios and aft deck lengths of rectangular nozzles on noise reduction through MDOE. Module validated in ANOPP2.
- Similar procedure ready for twin exhaust module, forward flight effect.



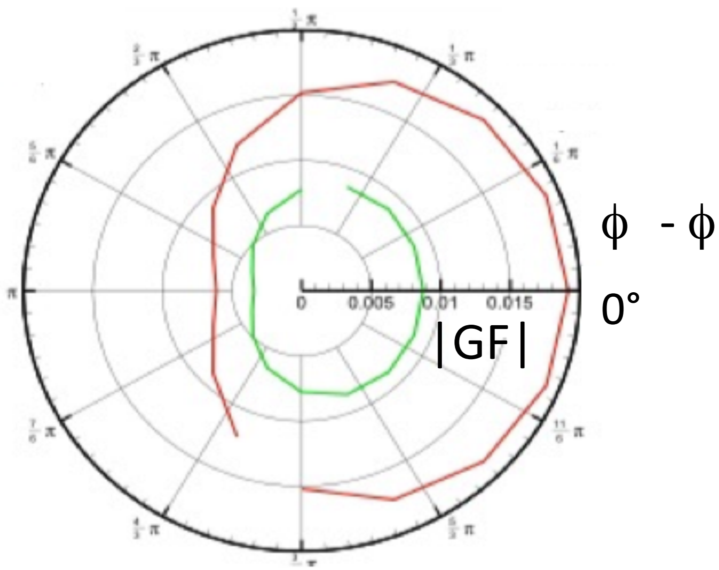


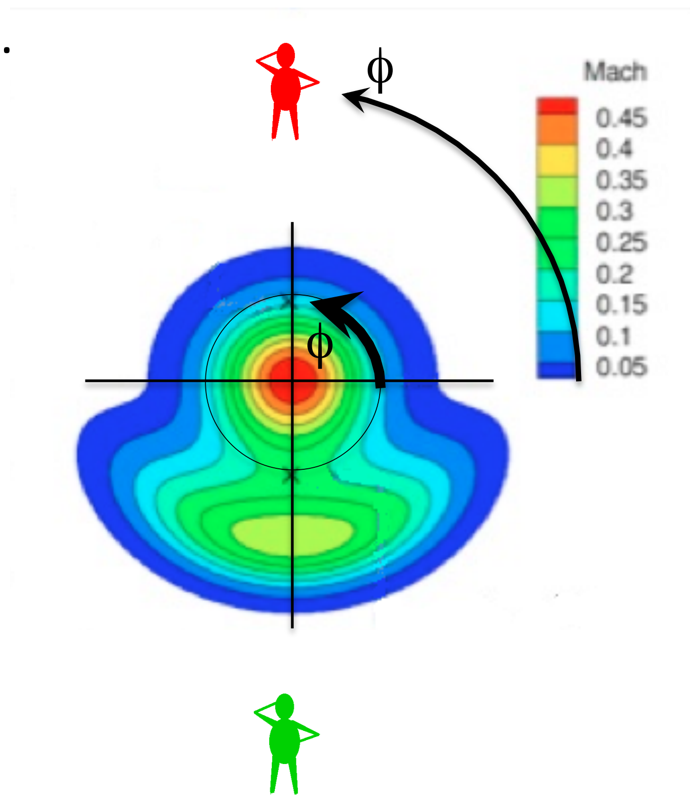
Venkat Iyer (venkat.r.iyer@nasa.gov) - AS&M/LaRC

T5.1.2 RANS-based Tools

51201 Generic NonAxisymmetric Greens Function

- Green's function relates how source couples with acoustic field.
- Fourier mode analysis allows arbitrary flow cross-section.
- Example below shows shielding by asymmetric flow profile.
- Code validated against known solutions.





T5.1.2 RANS-based Tools

51202 JeNo2 Hot Jet Source Model

- Published Tech Manual for JeNo2, including unsteady enthalpy source model.
- Continue validating for dual-stream exhaust with historical datasets.
- Use on parametric three-stream study (T5.2.1)

NASA/TM—2012-217743

An Empirical Temperature Variance Source Model in Heated Jets

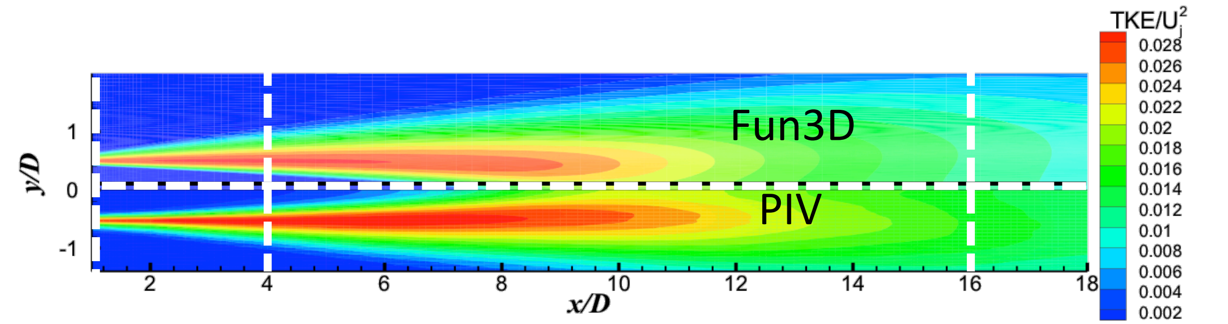
Abbas Khavaran
Science Applications International Corporation, Cleveland, Ohio

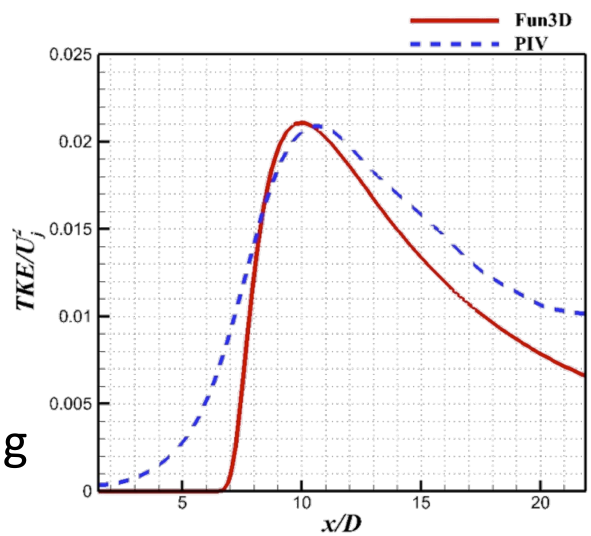
James Bridges
Glenn Research Center, Cleveland, Ohio

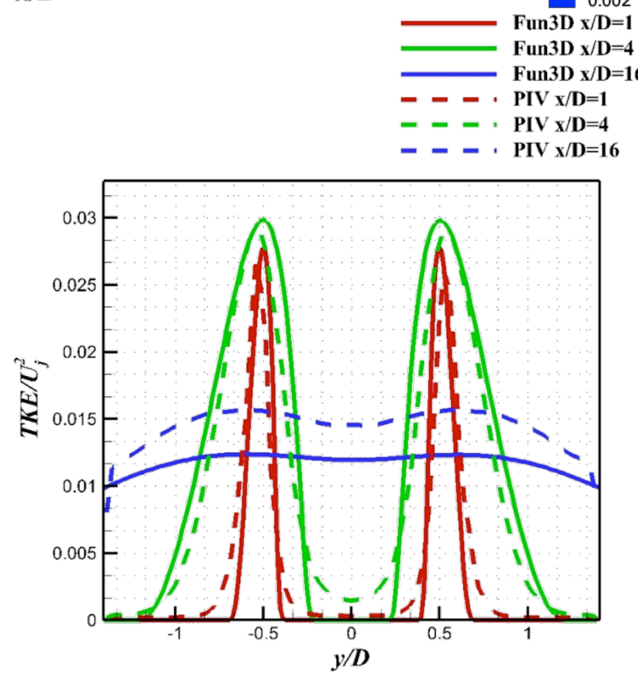
51203 RISN Jet-Surface Noise Model

FUN3D Validation

- NASA Langley Fun3D CFD Solver
  - Various M_j and *TTR*
- Comparison Shown
  - Convergent nozzle
  - $M_j = 0.50$
  - $TTR = 1.00$
- Not a typical result
  - Full eval in report
  - Recommend more research in turbulence modeling
- Move to unsteady simulations





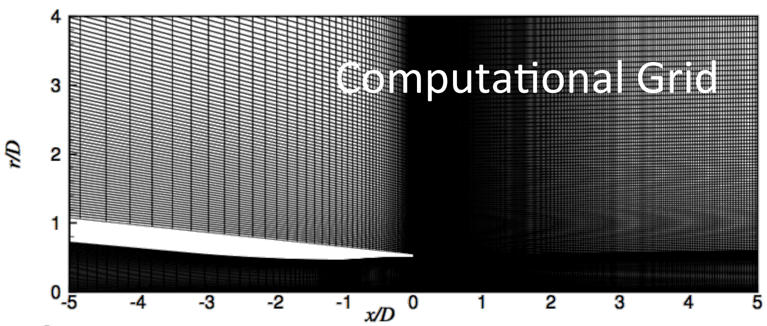


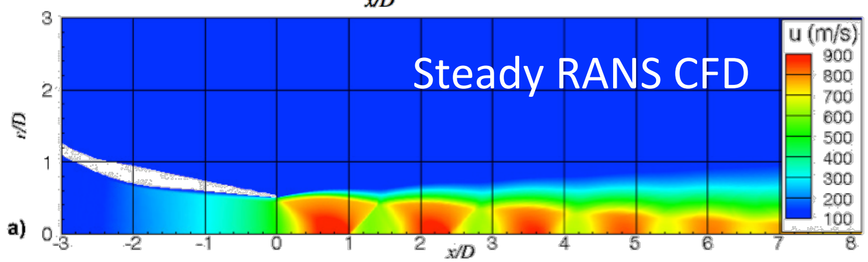
Matt Smith (Matthew.J.Smith@nasa.gov) - NASA Langley NIA Graduate Student
Steve Miller (s.miller@nasa.gov) - NASA Langley

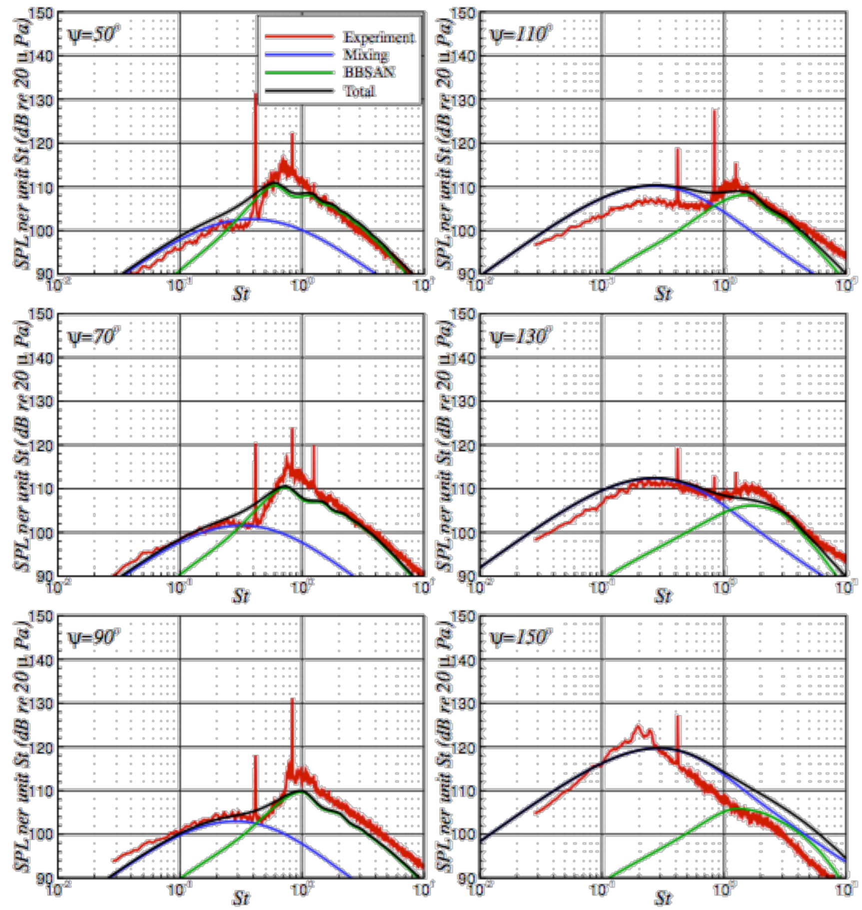
51203 RISN Jet-Surface Noise Model

RISN Jet Noise Prediction

- Jet Conditions
  - $M_d = 1.50$
  - $M_j = 1.294$
  - $TTR = 1.00$
- Capture jet noise intensity with locally parallel flow assumption

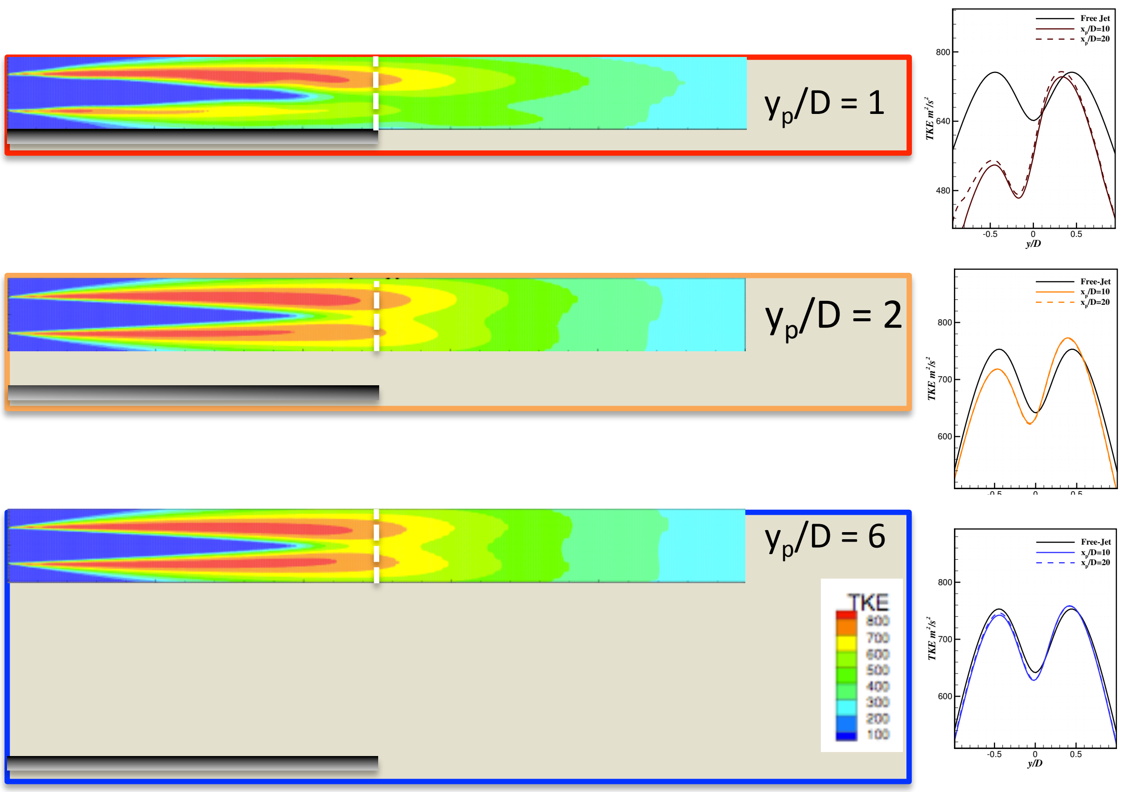


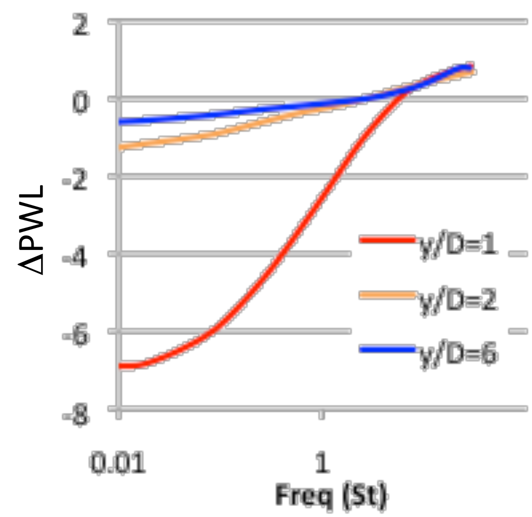




Effect of surface on TKE, Mixing Noise Component

- Mixing noise source reduced when jet in proximity to surface.
- Does not include Edge Dipole source, effect of diffraction.





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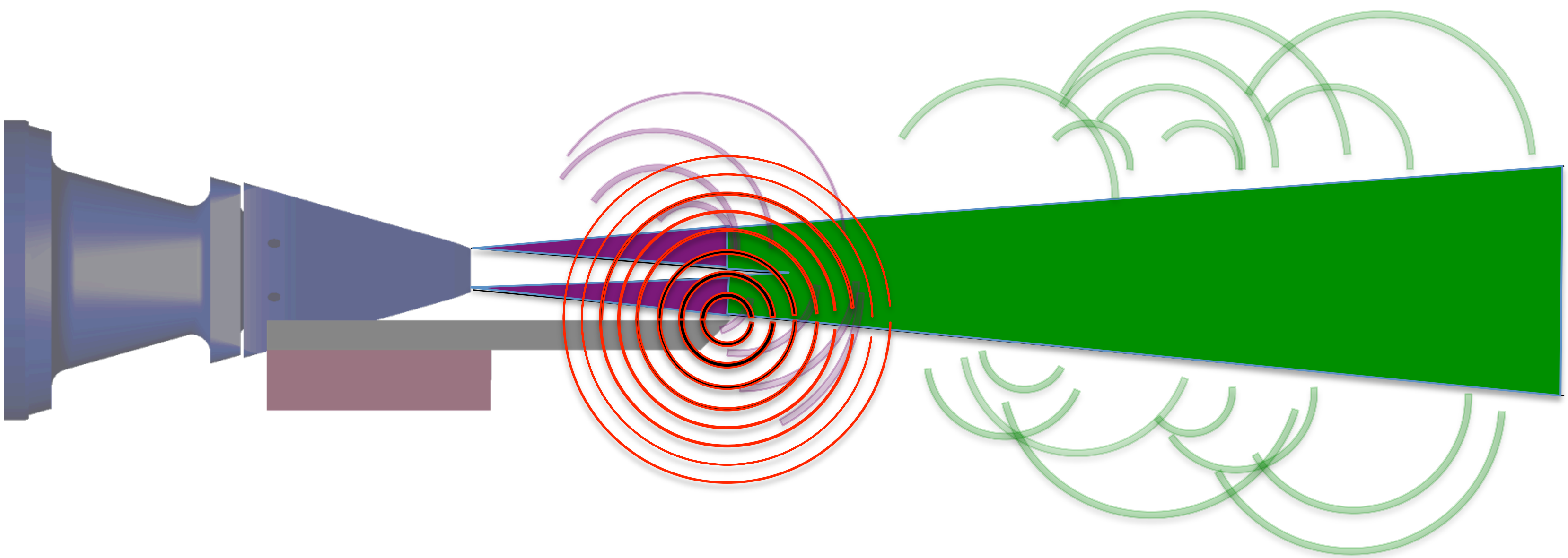
51203 Jet-Surface Noise Modeling

Rapid Distortion Theory for Edge Dipole

- Focusing on edge source produced by scattering of turbulent energy to the acoustic far-field by the downstream edge of a semi-infinite plate.
- Theoretical development, two-dimensional solutions
- Comparisons with high aspect-ratio jet experiments.



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T5.1.3 Time-Accurate Tools

Unsteady Separation Prediction via URANS

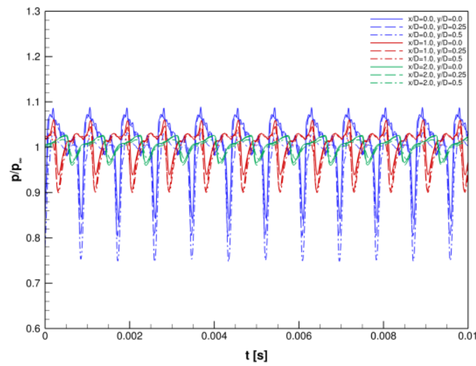
Purpose:

- Validate that unsteady RANS can predict unsteady separation in nozzles using known test case—overexpanded Con-Di nozzle.

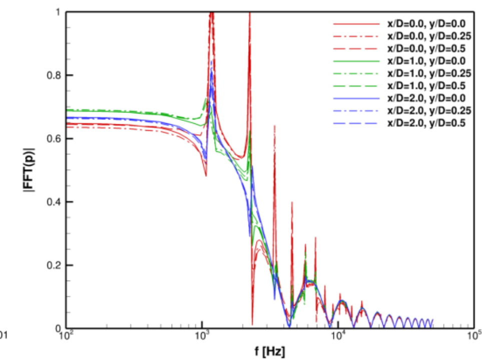
Method:

- Unsteady Reynolds-Averaged Navier-Stokes (RANS) simulations using Wind-US

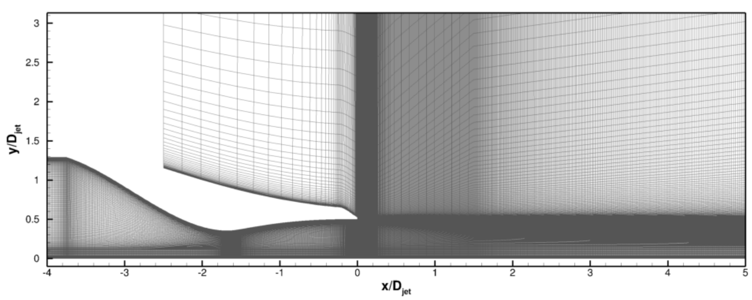
Unsteady Pressure



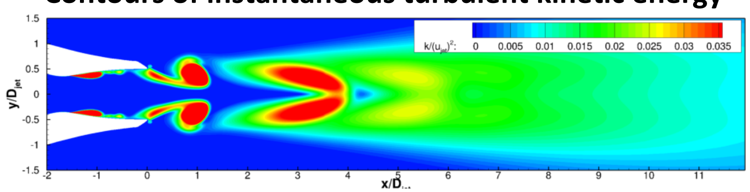
Power Spectral Density



Mach 2.2 Nozzle Grid

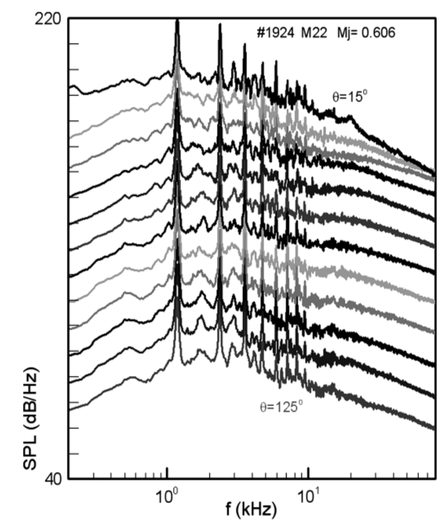


Contours of instantaneous turbulent kinetic energy



Outcome:

- Prediction of resonance with frequency 1145 Hz
- Experiment shows resonance between 1130 and 1175 Hz



(Zaman, Bridges, Brown, *AIAA Journal*, Jan 2010)

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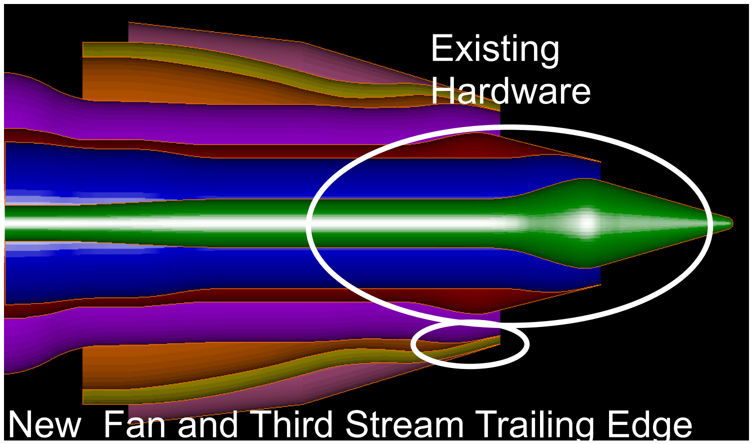
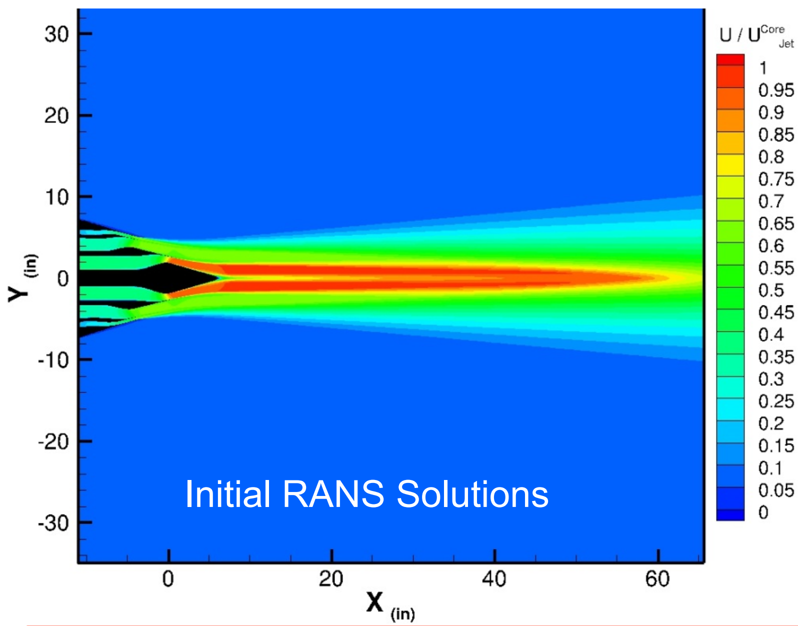
T5.2.1 Three-Stream Cycle Studies

52101 Three-stream Parametric Design Study





- Target Investigation
  - Reuse core internally plugged and externally plugged hardware
  - $2.5 < BPR_{tot} < 5.5$
    - BPR_{tot} = (fan+third)/core
  - $1.5 < NPR_{f,c} < 1.8$
  - $1.3 < NPR_t < 2.4$
  - $2.8 < NTR_c < 3.2$
  - $NTR_f = NTR_c = 1.25$
  - Range of area ratios determined from RANS
- Status
  - Base nozzle flow line established
  - Initial RANS solution complete
  - Parametric study initiated April 2013
  - Flow lines expected by June 2013
  - Fab for test Feb 2014

NPR = Nozzle Pressure Ratio, NTR = Nozzle Temperature Ratio

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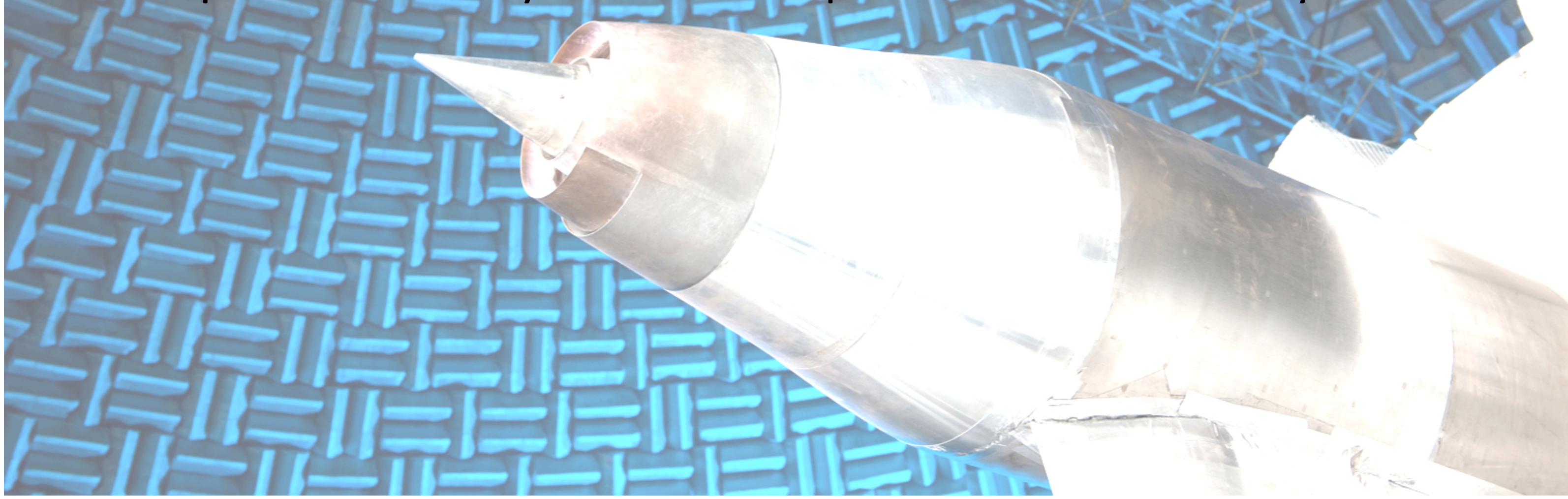
T5.3.1 N+2 IVP Gen2 Validation

NATR Validation Test

- Part of Lockheed Martin/GE N+2 System Validation Task
- IVP Gen2 flow lines approved 3/19/2013
- N+2 Sys Val contract with LM/GE phase 2 extension being worked to
  – Provide modified scale-model hardware
  – Provide data analysis to scale to certification values
- Expect delivery of model hardware Fall 2013.
- Complete data analysis and concept noise assessment by Feb 2014.



Steve Martens – GE Aviation
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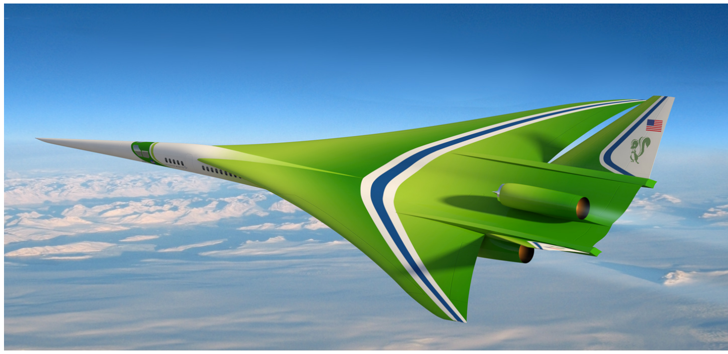
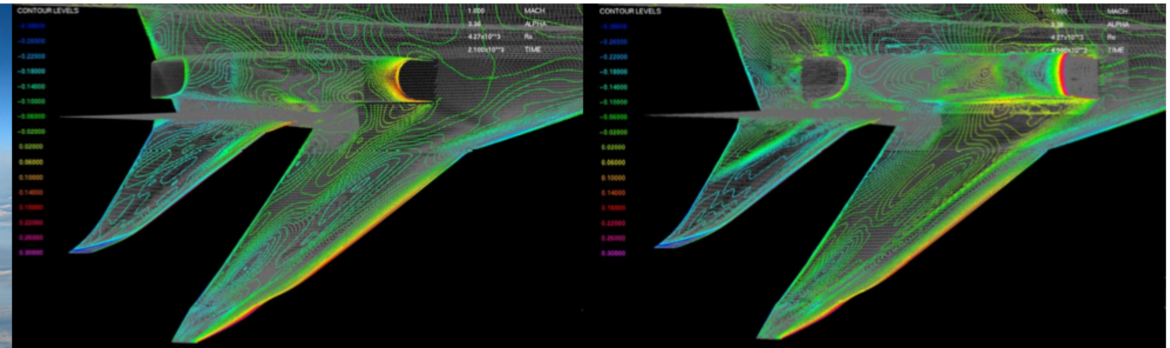
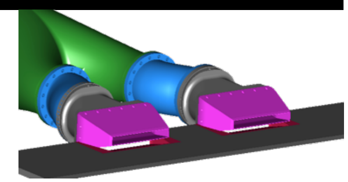
T5.3.2 TwinRect/Aft Deck Exploration

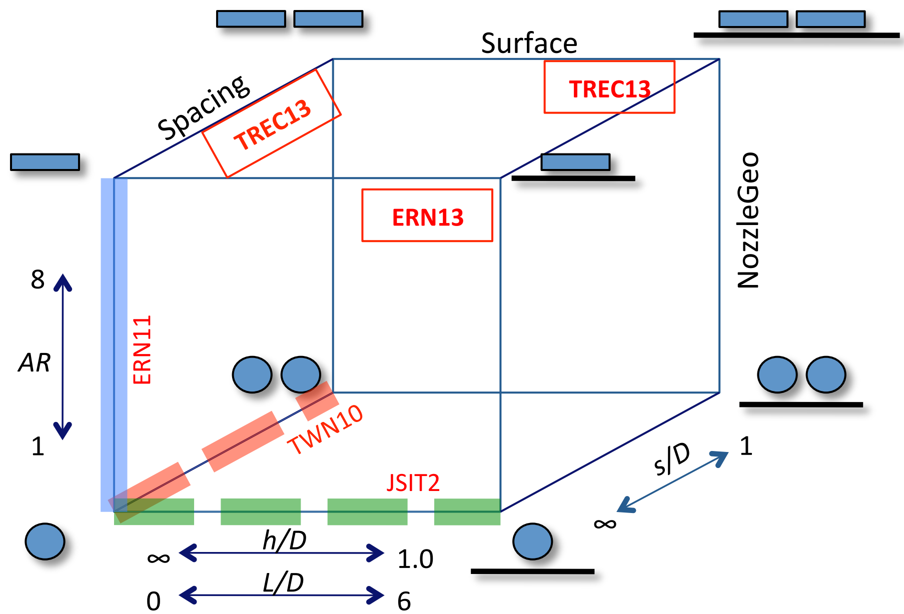
53202 TwinRect/AftDeck Test

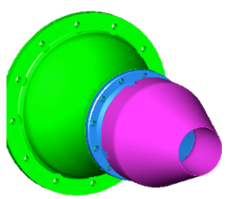






- Going from simple isolated to real integrated
- Variable space:
  - “the Cube”





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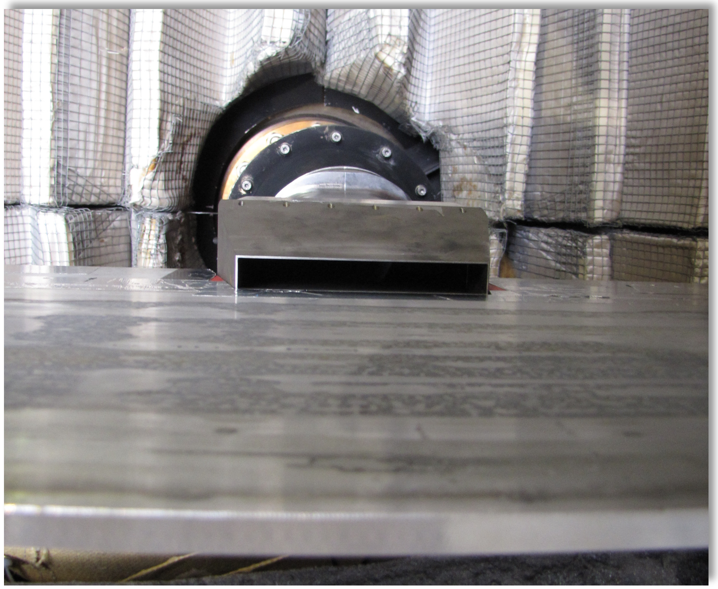
53202 TwinRect/AftDeck Test

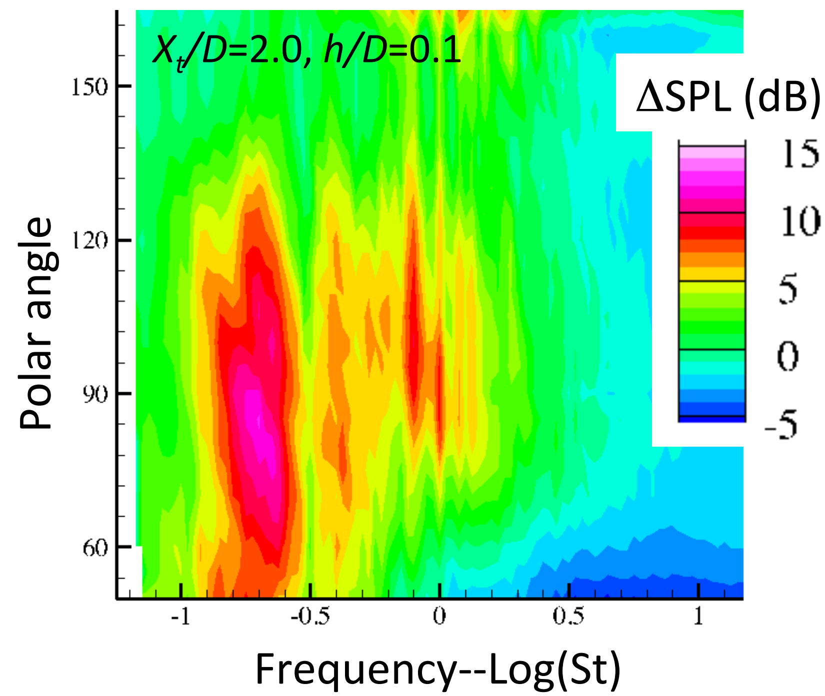
53202.1 ERN13—AftDeck SHJAR Test

- Initial phase (single/rectangle/surface) conducted on SHJAR
  - Cheaper, faster, proper semi-infinite shielding
  - Connection to Fixed Wing JSIT testing & modeling
  - Vary aspect ratio, surface length, standoff, jet Mach
- Testing completed 02/12/2013.
- Very high-quality, extensive database for modeling

$1 < AR < 8$
$0.6 < X_t/D < 6.0$
$0 < h/D < 5$
$0.5 < Ma < 0.9$



Directivity of surface impact on noise



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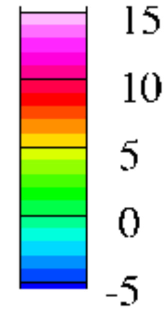
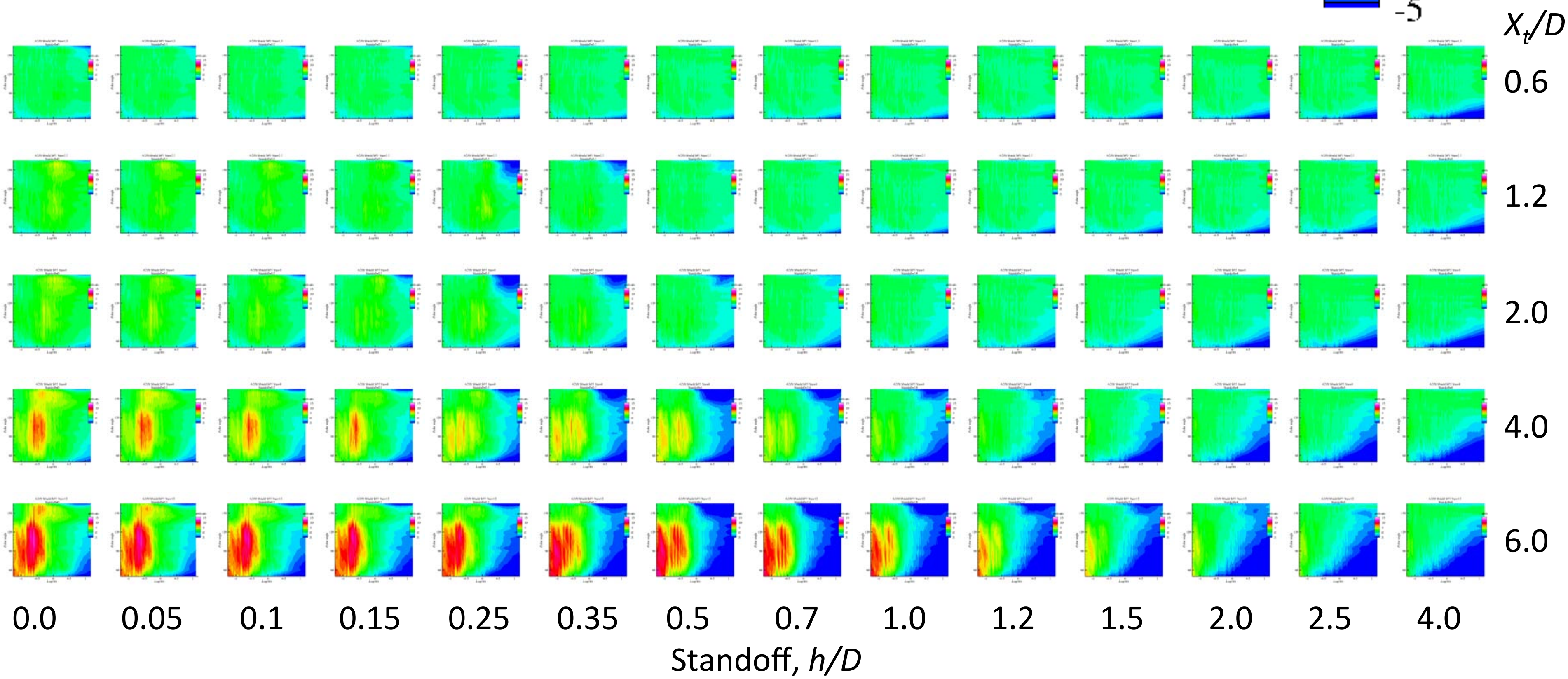
53202.1 ERN13—AftDeck SHJAR Test

Representative data

- *Ma*=0.9, AR=2:1, below aft deck
- Each plot shows spectral directivity of wall impact.
- Significant increase in noise in most configurations





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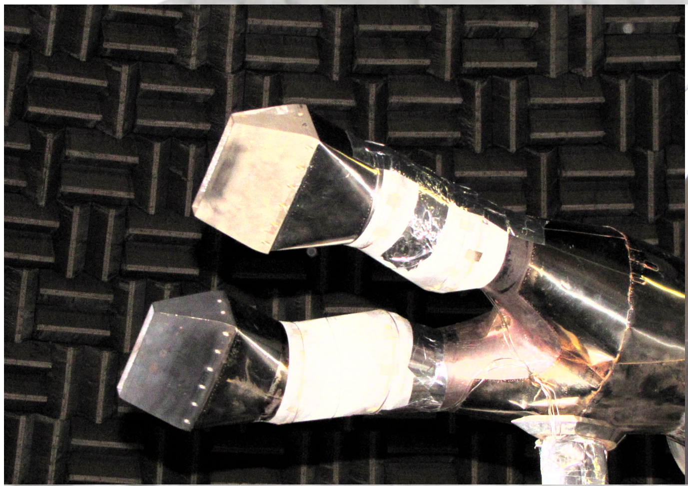
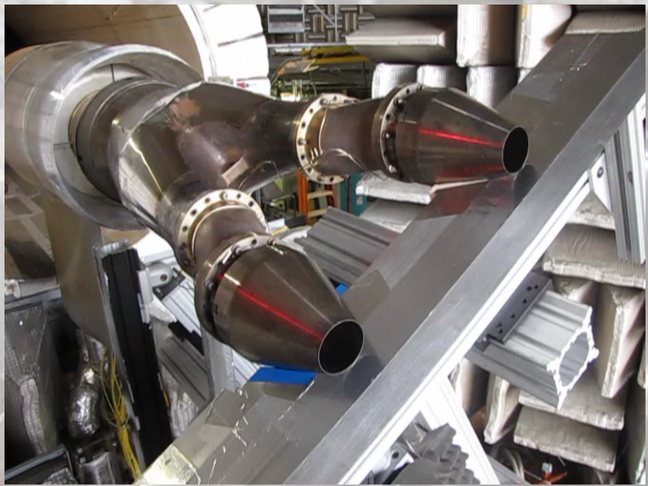
53202 TwinRect/AftDeck Test

53202.2 TwinRect/AftDeck NATR Acoustic Test





- Extensive CFD run to evaluate impact of rig wake on nozzle flow.
- Data tied to previous single rectangular, single nozzle with surface, and twin round nozzle data.
- Data shows rig-independence, different impact of second jet on surface noise than jet noise.
- Test will complete the Cube for twin rectangular nozzles with aft deck.
- Testing completed 4/11/2013.

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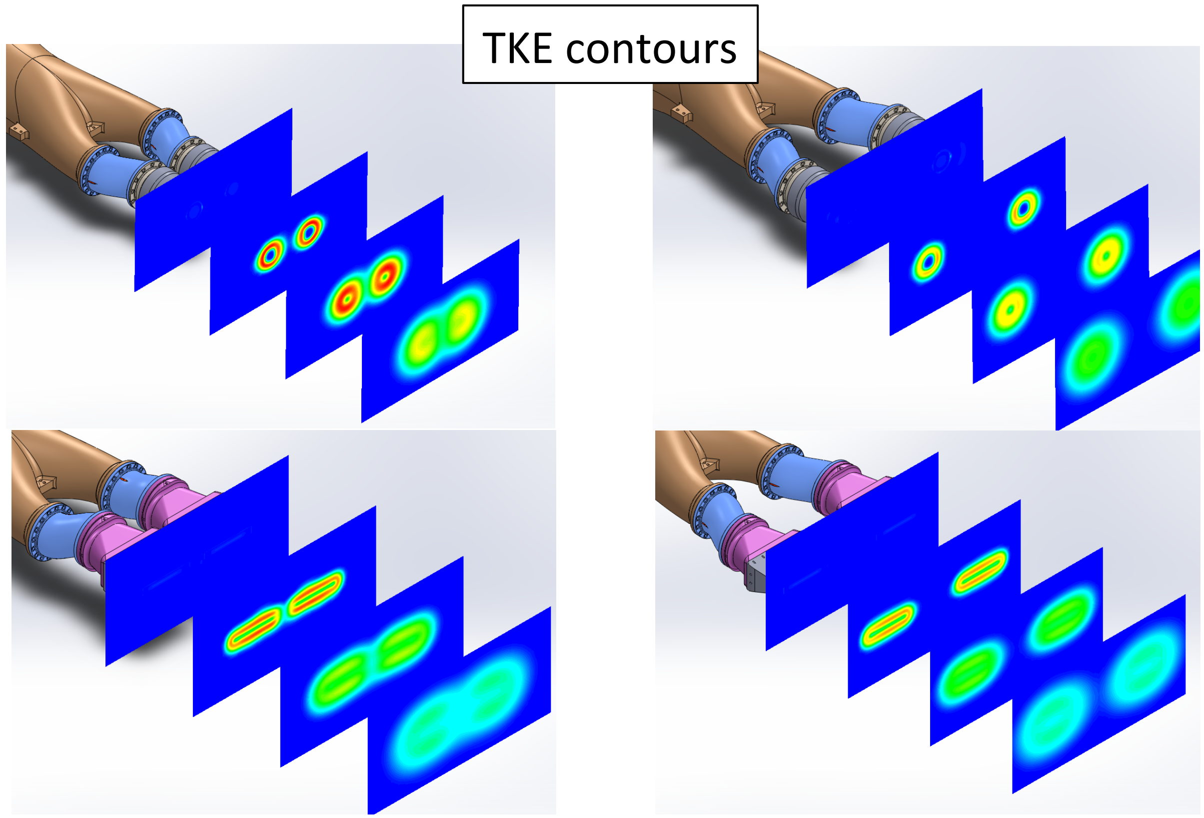
53202 TwinRect/AftDeck Test

53202.3 TwinRect NATR PIV Test

- Shown: pre-test RANS-CFD run to evaluate impact of twin.
- Complement jet-surface and rectangular nozzle PIV tests in 2012.
- Testing 4/22/2013 – 5/17/2013.

Round

8:1 Rectangle



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Summary

- High Speed Project focused on technical challenges of commercial supersonic aircraft, beginning with sonic boom.
- Project technical goals being met as TRL is being raised.
- Airport Noise Tech Challenge will develop and validate
  - low-noise propulsion concepts and
  - design tools to optimize them with other disciplines.
- 2016 milestone to demonstrate capability of meeting airport noise goals and of predicting sensitivities to design variables in cooperation with low-boom and aero efficiency disciplines.
- Very aggressive, multi-prong research program underway to put technologies in place to meet milestone.